## 5. Correlated Noise

### **Correlated Noise**

#### **Claim Term**

correlated noise

'839 Patent Claims 2 and 5 '180 Patent Claim 1

#### **CMU's Construction**

noise with 'correlation' among 'signal samples,' such as that caused by coloring by front-end equalizers, media noise, media nonlinearities, and magnetoresistive (MR) head nonlinearities.

CMU Brf. at 19

#### **Marvell's Construction**

noise having nonzero 'covariance' (see construction of 'covariance' above).

Marvell Brf. at 32-33

- The Dispute
  - Should "correlated noise" be accorded its ordinary meaning in engineering and statistics (Marvell) or its lay meaning with a list of examples (CMU)?

receiving said signal samples, said signal samples having

5. The method of claim 4 further comprising the step of

receiving said signal samples, said signal samples having

signal-dependent noise, correlated noise, or both signal-

dependent and correlated noise associated therewith.

## Claim Language

Method refers to a generic list of noise types

US 6,201,839 B1 shows the performance of the PR4 detectors at this density, FIG. 9 is similar to FIG. 7, except that the cour rates have increased. This is again the original signal and the FR4 ti metric function was selected, wherein each sample 2. The method of claim 1 further comprising the step of

PR4 shaping filter introduc (C2) still outperforms the re value of exploiting the cor FIG. 10 shows the error EPR4 detectors. Due to a h higher than in the previous of 4.4a. This is why the gra right by 2 dB in compariso the naturnal SCAWGONR is EPR4(Euc) and EPR4(C2) o about 1 dB, suggesti metric is more resilient to de in FIG. II where the S(AW of 10<sup>-5</sup> is plotted versus the operates at a linear density of the EPR4(C2) detector oper achieving a gain of about 1

signal-dependent noise, correlated noise, or both signaldependent and correlated noise associated therewith. very low number of symbols per a, this is the density where the detectors significantly lose performance that to the percolation of magnetic domains, also referred to as non-

selecting a plurality of signal samples, wherein each sample corresponds to a different sampling time Incar amplitude loss or partial signal ensure. FIGS: 12 and 13 show the performance of the PR4 and EPR4 families of sections at this density. The detectors at this density. The detectors with the C2 metric

joint probability density function of a subset of said signal samples;

'839 Patent Claim 2

have not been employed be The experimental evider ensitive sequence detect insensitive detectors. It has seformance margin bere the correlation insensitive ing density. In other words lation insensitive detector formance of the cor relation in the poise Qualitatively, the higher samples, the greater will be and its cornelation inscessi

percolation of domains, sta-only be undone with a nonl

While the present inven-junction with preferred on lications and variations wil skill in the art. For examp between adjacent signal sar sequence of symbols three

The foregoing description intended to cover all such modifications and variations What is claimed is: 1. A method of determining branch metric values for inches of a trellis for a Virterhi-like detector, compri selecting a branch metric function for each of the branches at a certain time index; and

outperform the other two metries. The error rates are quite high in all cases. This is because at the symbol separations

of 2.9a, nonlinear effects, such as partial erasure due to

applying each of said selected functions to a plurality of 45 signal samples to determine the metric value corre-sponding to the branch for which the applied branch

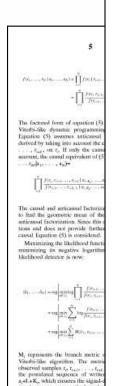
signal samples less a phrality of target values normal-ized by a trellis branch dependent covariance of said signal samples;

calculating a third value representing a quadratic of a subset of said signal samples less a plurality of channel larger values normalized by a trellis branch dependent covariance of said subset of signal samples; calculating the branch weight from said first, second, and third values, and

'839 Patent Claim 5

## Specification

 Patents describe correlated noise using mathematical terms



under different assumptions on the considered. Euclidian branch meeric. In the samples are realizations of independent Gaussian readom variables ance or. This is a white Gaussian implies that the correlation elistance pld's have the same form for all ne length is assumed to be K-K, K-K, eading and trailing ISI lengths, leading and trailing ISI lengths.

Correlation-sensitive branch metric. In the most general case, the correlation length is L>0. The leading and trailing ISI lengths are  $K_l$  and  $K_t$ , respectively. The noise is now considered to be both correlated and signal-dependent. Joint Gaussian noise pdfs are assumed. This assumption is well justified in magnetic recording because the experimental evidence shows that the dominant media noise modes have Gaussian-like histograms. The conditional pdfs do not factor out in this general case, so the general form for the pdf is:

$$\frac{f(r_{i+1}, \dots, r_{i+L} \mid a_{i-K_l}, \dots, a_{i+L+K_t})}{f(r_i, r_{i+1}, \dots, r_{i+L} \mid a_{i-K_l}, \dots, a_{i+L+K_t})} =$$
(11)

$$\sqrt{\frac{(2\pi)^{L+1} \det C_i}{(2\pi)^L \det c_i}} \frac{\exp[\underline{N}_i^T C_i^{-1} \underline{N}_i]}{\exp[\underline{n}_i^T c_i^{-1} \underline{n}_i]}$$

'839 Patent 6:36-52

# Extrinsic Evidence: Technical Treatises

- Marvell construction identical to statistical meaning
  - Uncorrelated variables have zero covariance
  - Correlated variables have nonzero covariance

If  $Cov(X_1, X_2) = 0$ , then the random variables  $X_1$  and  $X_2$  are said to be uncorrelated; if  $Cov(X_1, X_2) \neq 0$ , then they are *correlated*. Independent random variables are always uncorrelated, but correlated random variables are not necessarily independent in general.

Polyanin and Manzhirov, Handbook of Mathematics for Engineers and Scientists, at 1061 (2007) (Marvell Exh. 36)

2.3.2 Correlation and Covariance

Two random variables are said to be uncorrelated if  $E(X_iX_i) =$  $E(X_i)E(X_i) = m_i m_i$ . In that case, the covariance  $\mu_{ij} = 0$ . We note that when  $X_i$ 

The second joint centralized moment is called the covariance, and is denoted by  $K_{xy}$ :

$$K_{XY} \triangleq E\{(X - m_X)(Y - m_Y)\}.$$
 (2.21)

It is easily shown (exercise 3) that

$$K_{XY} \equiv R_{XY} - m_X m_Y. \tag{2.22}$$

The correlation and covariance are each important measures of the interdependence of two random variables. If

$$K_{XY} = 0, (2.23)$$

then X and Y are said to be uncorrelated. This terminology results from the

fact that  $K_{XY}/\sigma_X\sigma_Y$  is referred to as the correlation coefficient. If

John G. Proakis.

Digital Communications, at 35 (3d ed. 1995)

(Marvell Exh. 35);

See also Proakis Decl. at ¶¶ 42-43

Gardner, Introduction to Random Processes with Applications to Signals and Systems, at 32-33 (1986) (Marvell Exh. 24)

## CMU's Arguments Fail

 CMU's construction is grounded in its incorrect construction of correlation.

- CMU's list of examples from the specification is not helpful and improper.
  - "[A]Ithough the specification often describes very specific embodiments of the invention, we have repeatedly warned against confining the claims to those embodiments." Phillips, 415 F.3d at 1323.
  - "This Court has cautioned against limiting the claimed invention to preferred embodiments or specific examples in the specification."

Texas Instruments, Inc. v. U.S. Int'l Trade Comm'n, 805 F.2d 1558, 1563 (Fed. Cir. 1986).